Detection of chaos in RR Lyrae models

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1 Motivation

Dissipative dynamical systems with relatively small linear growth rates are usually not expected to show chaotic behaviour. However, chaos investigations of these systems are justified in the light of new discoveries. The period doubling phenomenon was recently observed in RR Lyrae stars with the *Kepler* space telescope ([3]) and has been explained by hydrodynamic calculations ([1]). The period doubling state is usually not "far" from chaos. We analyse two peculiar model solutions of the Florida-Budapest turbulent convective hydrodynamic code that suggest that the bifurcation cascade may evolve to chaos in these systems.

2 Results

We used the global flow reconstruction technique, a nonlinear analyser tool that is suitable to detect chaos and define quantitative information of the system ([2]). We have successfully reconstructed both models and determined the Lyapunov dimension to be 2.22 ± 0.10 in the case of Model A, and 2.17 ± 0.08 of Model B. These values are in agreement with the broad structure of the return maps on Fig. 1. Return maps display a more complex look compared to the usual quasi-one-dimensional

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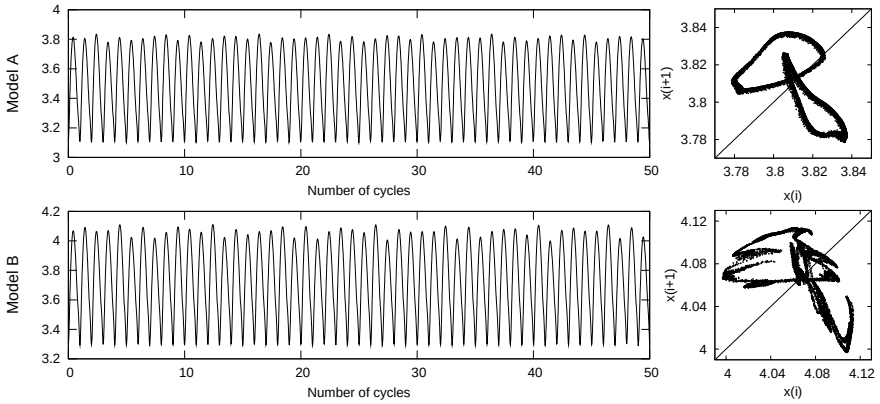

Fig. 1 Left panels: Radius variation of the two models. Right panels: Return maps for successive maxima.

tent or parabolic shape that chaotic systems have with Lyapunov dimension of $2+\varepsilon$. We iterated the nonlinear models for 10^5 cycles to rule out any transients but the return maps remained unaltered.

The kinetic energy changes less than a percent between pulsation cycles, in agreement with typical linear growth rates in RR Lyrae models.

Radius variations of RR Lyrae hydrodynamic models were suitable for the global flow reconstruction method and thus detection of chaotic behaviour. Luminosity variation was also studied in this manner, but the reconstruction was not successful. We believe that this is probably due to the more complex nature of the light curves.

The observations of *Kepler* RR Lyrae stars suggest some irregularity in the period doubling, but a similar analysis can only be performed after a suitable transformation of the light variation.

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